PEER REVIEW OF OBSERVATION TOWER REPORT

Prepared for Project 12G1S-12

PENINSULA STATE PARK

November 4, 2015

For:

Wisconsin Department of Natural Resources
Engineering & Construction/Lands Division

Attention:

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Introduction

MSA Professional Services was retained by Glen Clickner, Section Chief – Engineering & Construction/Lands Division of the Wisconsin Department of Natural Resources to prepare a peer review of the report prepared for Project 12G1S-12 'Structural Condition Assessment' of the Observation Tower at Peninsula State Park by Edge Consultants.

Scope of Services

The agreed to scope of services was as follows:

A. Review of the design load and material property assumptions
B. Review of the structural modeling performed
C. Recommendations for conducting additional testing
D. Verification or adjustment to the recommendation to close/raze the tower
E. General thoughts on rehabbing the current structure

The scope of services did not include a site visit, nor require a second computer analysis.

Materials Provided

MSA was provided a copy of the report by Edge Consultants, which included their findings, as well as digital images, the computer model, loads and materials assumed. There were no original drawings available as mentioned in the Edge report.

MSA PEER REVIEW

A. Review of the design load and material property assumptions

<u>Loads</u>

The basic loads applied to the computer model were dead load weights of the materials of the tower; live load, snow load, wind load and seismic load came from current building code requirements found in ASCE7-05, referenced in IBC 2009. These are the same engineering documents used by engineers across the USA. I did follow their numerical calculations for the loads since this is the most important data compiled for input in load combinations in every computer program. The largest gravity load is the occupancy (people) live loading of 100 psf used for stairs, observation platforms and stair landings. Snow, wind and seismic loads I also agreed with. Wind required consideration as a trussed tower, while snow required engineering judgment due to the open nature of the structure. Snow drifts turned out not to be required.

Materials

A Historical Record of 'Properties for Rolled Shapes in Steel and Wrought Iron', indicates that in 1932 eyebars could be considered to have a yield of 36 ksi, so that was a correct choice by EDGE. The selection for allowable stresses in wood that are treated or not treated really depends on their computer program and is not specifically stated. The National Design Specification Supplement for Design Values for Wood Construction (2001 Edition) states for Douglas-Fir-Larch No.1 that allowable bending stress would be 1000 psi and Modulus of Elasticity would be 1,700,000 psi used in deflection calculations. These are reasonable values for a preliminary analysis. Treated lumber members are assumed to be Spruce-Pine-Fir No.1/No.2 which has an allowable bending stress of 875 psi and a modulus of elasticity of 1,400,000 psi. Only a duration of load factor greater than 1.6, meaning impact loading, would reduce these allowable stresses. I do not consider impact loading a factor for this structure.

I take no issue with EDGE's load magnitudes or material allowable stress choices.

B. Review of the structural modeling performed

The structural program that has been used appears to be RISA 3D, which is popular, but not a program used often in the MSA offices. RAM Structural is our preferred software; however, they are both finite element analysis programs. There are enough similarities to assess correct use of connection types and load assignments to members. Hinges are the correct designation at the bottom of the four columns and for the central stair tower, while pin ends are correct for the floor platform joists at each of the three levels. The diagonal rods are shown with a pin at each end, which matches the eyebar end that exists. Loads appear to be applied in the correct direction and on the correct members for the individual load cases of wind, snow and live load. Load combinations are not shown in the report, but a summary of maximum stress levels are given for the largest load combination. The results for specific types of members appear to be of a reasonable relative magnitude given their location within the structure's overall height. Also, it is stated clearly in the EDGE Report that new, non-deteriorated members were assumed in the model and that actual deteriorated member properties would decrease their capacities from that shown in their table.

The foundations were excluded from the analysis.

I take no issue with their Structural Modeling approach; however I do question the total application of occupancy live load on all levels and all stair stringers and landings at the same time.

Author's discussion: Typical building design requires engineers to apply stair live loads and floor live loads (taking into account live load reductions when possible) together at all levels together to obtain maximum gravity loads on columns. This is to account for fire conditions when everyone on each floor runs to the stairs. This is the only time all occupants load all the stairs simultaneously with the floor areas closest to those stairs also being loaded.

An observation tower could be given some alternate consideration, rather than treating it the same as a typical building. There should be the possibility to reduce the live load or pattern it in some logical way.

The end result would be to reduce the load on the structure and thus the stresses in the members. I wonder if it is possible to accept a uniform 35 psf live load, which is the same as the snow load, thus making the stresses acceptable throughout the structure under gravity loading, as it states in the EDGE Report.
The EDGE Report states that they had a discussion about public traffic flow and it was decided to stay with the 100 psf live load as most appropriate of the loading expected on the tower. I think this discussion bears revisiting with park staff. Maybe they did not understand that EDGE was loading every level, stair and landing with 100 psf simultaneously.

Suppose, since the top level is likely the most desirable viewing point, that the 100 psf is left over that entire level and even the stair stringers leading to that level as well. Then reduce to 40 psf for all levels from there down, including the stair stringers and landings.

One last comment. To achieve 100 psf bodies would have to be standing tight against each other, occupying 1 foot by 1.5 foot and weighing 160 pounds. That would mean at the top level, which is 18 feet square (minus the stairwell), 189 people squeezed together. How realistic does this sound? I venture a guess that the railing cannot handle the lateral load, and given the images of the railing deterioration at each level, I am surprised one of them has not already failed.

Lastly, the Edge Report indicates the diagonal rods are overstressed under full wind loading. I do not know what load combination produced that result; but most likely it was 0.6xDL + WL. There would be no people on the tower if the wind was 90 MPH.

C. Recommendations for conducting additional testing

Additional testing would provide insight into the degree of degradation of members if it is decided that the structure should be repaired. Twelve cores were taken and that information is included in the EDGE Report. The connections adjacent to the diagonal eyebars at each level, where bolt holes were drilled and water could easily enter the wood and damage the core are logical locations to check.

D. Verification or adjustment to the recommendation to close/raze the tower

It is very easy to agree with the findings of the EDGE Report. They have followed sound engineering procedure in all respects. Yet the live load issue I have raised above could be an adjustment that changes the computer output to a more favorable stress level. There will need to be more discussion on realistic occupancy levels if there is any hope of saving the structure. I did not see nodal displacement output, so I cannot speak to those results.

E. General thoughts on rehabbing the current structure

Several items come to mind with regard to potential rehabilitation of the tower. The application of occupancy live load is the first item, and it was discussed above in detail.

The second is the looseness of the diagonal rods at each level, resulting in large lateral deflections with people at the top of the tower. A unique mechanical property of wood is creep under long term compression loading over time. This happens to beams within their compression fibers as well columns in compression fibers. Only concrete exhibits a similar inelastic creep behavior in compression. The dead load weight of the tower has been applied to the 4 corner columns for 80 years, if that load could be removed only the elastic portion of the compression deflection would relieve itself. The creep portion would remain – about 50%. Add to this any moisture change that may have resulted if the timbers were green during installation. The timber rotting at bolted connections loosens the structure as well. All these issues would affect the tightness in the rods.

There were turnbuckles visible in several of the digital images, so there is potential to adjust the tension in the eyebolts. The eyebolts and rods appear to only have a light corrosion on them and therefore they are salvageable. I contend they could be re-tensioned one at a time to be able to individually adjust tension at each level. This would stiffen the tower considerably. Investigation of the eyebolt connections at the round columns for dry rot and subsequent epoxy repair would need to be done first.

There are epoxy repair products available on the web from such companies as Abatron, Inc., and SIKA.

Given that a satisfactory occupancy pattern or magnitude is found to be acceptable to Code Officials, there is still the economics of a repair. Certainly there is more to repair than what was found by the cores already taken – additional testing by methods suggested by the EDGE Report would be a necessary next step.

The epoxy repair process is slow; however, repair of the railings is also required at each level – this could be done simultaneously. The stair treads/stringers that require replacement, and assorted connections could also be fixed. Members found unrepairable could be removed and replaced with new wood members or equivalent size aluminum tube members.

The concrete foundations should be checked for soundness, vertical displacements, etc. There were unusual cold joints in the first two images, unexplained in the EDGE Report.

Concluding Remarks

The EDGE Report is very compelling – particularly the conclusions, images and the tabled maximum over stresses for arriving at the conclusion to close the structure. I would have no alternative but to agree with them, except for the difficulty with the application of the 100 psf live load for this type of structure placed everywhere simultaneously on the computer model. The idea for repair may seem far-fetched; but not so if local officials can be made to see the logic of my occupancy live load argument.

The economics of a new galvanized steel tower may outweigh repair of the existing tower and give more peace of mind. I felt it was worth exploring an approach to try and salvage the existing structure with repair and an open mind to live load.

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Respectfully Submitted,

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On behalf of MSA Professional Services